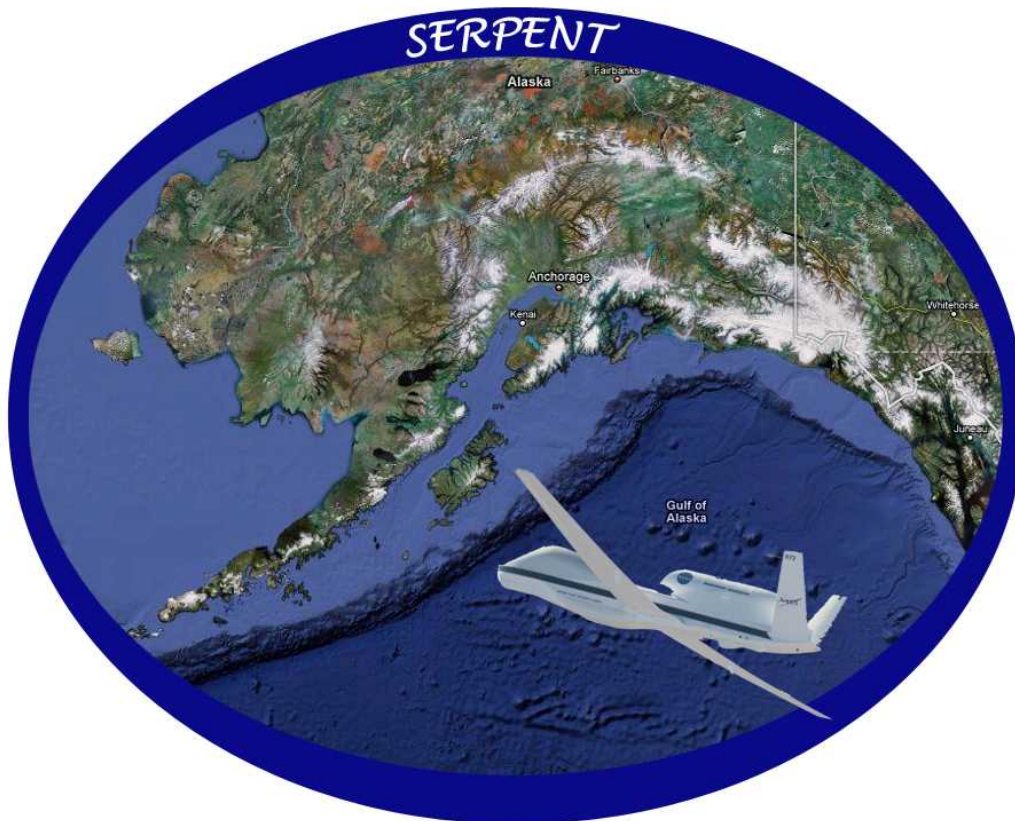


## **Serpent:** **Magnetic Signatures of Serpentinized Mantle and MesoScale Oceanic Variability** **Along the Alaska/Aleutian Subduction Zone**



**November 6, 2009**

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## 1.0 Executive Summary

We propose to carry out a suborbital magnetic survey of the Aleutian subduction zone using NASA's Global Hawk to test the magnetic **serpentinite** hypothesis. This hypothesis states that dewatering of the descending slab within subduction zones produces an observable static magnetic signature through the formation of serpentinite in the overriding mantle. This signature may serve as a predictor of the location of large megathrust earthquakes and their associated tsunamis. Magnetic field measurements from 20 km (sub-orbital) altitude are essential to the testing of this hypothesis; analysis shows orbital and/or near-surface measurements are not likely to provide sufficient sensitivity and uniform calibration to confirm or reject the hypothesis, nor to consistently map its presence around the world. Static and dynamic magnetic signatures from the motion of seawater in the earth's magnetic field have the potential to confound an evaluation of the magnetic serpentinite hypothesis. Through a combination of modeling and exact repeat surveys over the subduction zone, spaced weeks to as much as six months apart, we can study the magnetic signature of the motion that characterizes the mesoscale oceanic circulation in order to develop the best possible corrections for lithospheric imaging, and elucidating the intrinsic and unique oceanic information content in the magnetic fields for the first time ever.

The role of water in subduction zones, and in the overlying ocean, can be traced by sustained suborbital observations of the magnetic field. At critical depths of 40 to 50 km, subducting ocean crust goes through important metamorphic changes that release large amounts of water into overriding mantle rocks. Introduction of water into the mantle produces serpentinite, a highly magnetic, low-density rock. Thermal models indicate that, in many of the world's subduction zones, this part of the mantle is cooler than the Curie temperature of magnetite, the most important magnetic mineral in serpentinite, and thus large volumes of mantle in subduction-margin settings should be magnetic. Indeed, analysis of magnetic data from some subduction zones indicates that magnetic mantle can be detected in long-wavelength magnetic anomalies. The presence of serpentinite in subduction margins has two important links to large within-slab and giant megathrust earthquakes, and associated tsunamis. First, release of water from the subducting slab is thought to embrittle the slab, thereby promoting within-slab earthquakes (M 7-8). Thus, we expect to see a spatial association between this type of earthquake and mantle magnetic anomalies. Second, in cool subduction margins, the down-dip limit of megathrust earthquakes (M 8.0-9.6) is controlled by the slab's first encounter with **serpentinized** mantle. Again, we expect to see a spatial association between these devastating earthquakes and magnetic anomalies. The magnetic serpentinite hypothesis can be tested by comparison to free-air gravity, geologic, topographic, and bathymetric data of comparable resolution.

Significant static and dynamic magnetic fields also originate as a consequence of oceanic flow in electrically conducting ocean water above the subduction zone. Although these signals are of much lower amplitude than the magnetic field associated with serpentinite, they can have significant power at short spatial scales, and thus have the potential to confound estimated magnetic source depths that rely on inferences from the horizontal magnetic gradient. Although a source of noise from the perspective of imaging the lithosphere, the motionally induced magnetic fields also present new opportunities for remote sensing in ocean and climate studies.

This proposal is relevant to the goals of NASA's Earth's Surface and Interior program by virtue of its characterization of the link between magnetic serpentinite in subduction zones and within-slab and megathrust earthquakes, and to NASA's climate program by virtue of its exploration of the magnetic signature of ocean current systems and their variability. These measurements apply to the scientific goals of multiple Earth Science focus areas, and range from exploratory (magnetic remote sensing of ocean flow) to a more refined quantification (magnetic serpentinite hypothesis) of hypothesized processes. The proposal complements and augments current satellite observational capabilities, and will enable future NASA geomagnetism missions by qualifying a new TRL-6+ helium magnetometer. This magnetometer, and its successors, will allow us to take advantage of spacecraft miniaturization and enable the efficient collection of in-situ magnetic field measurements over large volumes of space via a satellite constellation approach.

The Aleutian subduction zone is the target of this program. The 24 magnetic surveys, and repeat surveys, will be flown by NASA's Global Hawk, flying from NASA's Dryden facility. The helium magnetometer, provided by Robert Slocum of Polatomic, has a long and successful history at NASA, with variants having flown on NASA's planetary missions. These helium magnetometers are the product of successful SBIR programs for NASA's Earth Science program, and have also been successfully integrated into DoD aircraft. The magnetometer is at a high technical readiness level (TRL-6+), with several thousand having been manufactured for the Navy's anti-submarine program.

The project will be led by scientists with strong records of success in previous magnetic field investigations while the instrumentation will be developed and integrated by engineers with extensive magnetics and Global Hawk experience. The PI is Dr. Michael E. Purucker of Raytheon, located within the Planetary Geodynamics Lab at Goddard Space Flight Center, and the Deputy PI is Dr. Guan Le, a NASA civil servant and scientist. Purucker and Le worked together on NASA's successful ST-5 constellation mission. R. Blakely (USGS), our lead scientist for the solid earth part of this effort, is the author of the magnetic serpentinite hypothesis. S. Maus, our lead scientist for data analysis, has served in this same position as part of the CHAMP satellite program, and is one of the authors, along with Purucker, of the World Digital Magnetic Anomaly Map. The ocean science part of the effort will be led by G. Egbert (OSU), ably assisted by S. Maus and R. Tyler. The project will be managed by Photon Research Associates, Inc (PRA), a wholly owned subsidiary of Raytheon. PRA is contained in Raytheon's Space and Airborne Systems (SAS) business unit. SAS has been involved as a subcontractor to Northrop Grumman since the inception of the Global Hawk UAV program. The PM for the project is David Zimmerman of Raytheon PRA. Pileih Chen of Raytheon SAS will serve as the subject matter expert for Global Hawk integration, and Dr. Jeffery J. Puschell, Raytheon SAS will be the Program Advisor. For this proposal, Raytheon is teaming with scientists and engineers from Polatomic, the US Geological Survey, NASA's ESPO and Goddard Space Flight Center, the University of Colorado, Oregon State University, and the University of Washington.

A 24-month project development phase will be followed by 16 months of observation, ending with a 12 month science data analysis phase. The length of the development phase is a consequence of the need to modify and flight test the Global Hawk nose stinger, and to fully characterize the magnetic environment of the Global Hawk. The proposed mission will encompass 5 test flights and 24 operational flights of the Global Hawk. The total cost of the project is 20 million dollars.